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RECENT FAILURES OF WEATHER SATELLITES

HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

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ON

RECENT FAILURES OF WEATHER SATELLITES

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RECENT FAILURES OF WEATHER SATELLITES

THURSDAY, AUGUST 2, 1984

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, DC.

The subcommittee met, pursuant to notice, at 11:05 a.m., in room SD–138, Dirksen Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

Staff members assigned to this hearing: Charlie Faust, professional staff member and Pat Windham, minority professional staff member.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. Good morning. Welcome to this hearing of the Science, Technology, and Space Subcommittee of the Senate Commerce Committee. We are here today to discuss the recent failure of two of the Federal Government's weather satellites.

The National Oceanic and Atmospheric Administration, or NOAA, operates two meteorological satellite systems with a total of four satellites. These systems provide much of the information used in developing weather forecasts. In the past few weeks both systems have been weakened by the unexpected failure of two satellites. Our meteorological satellite capability, therefore, has been cut in half.

Today, we will discuss what effect these failures will have on our ability to forecast weather conditions, what our interim response will be, and what can be done to improve these systems in the long term.

The satellite with which the public is most familiar is called GOES. The GOES satellite monitors the Earth's atmosphere from more than 22,000 miles in space, and sends signals that are processed into the images that we see on television weather forecasts and in the newspaper each day.

This week, the GOES satellite has been in the news for a different reason. This past Sunday evening, the GOES-East satellite which monitored the eastern half of the United States suddenly stopped functioning. Its replacement is not due for launch until May of 1986.

Fortunately, the healthy GOES-West satellite can be moved to a central location and monitor the entire Continental United States. The downside to this is that a centrally located GOES cannot see much of either the Atlantic or Pacific Oceans which produce most of our unexpected severe weather.

During the upcoming hurricane season, for example, our ability to monitor developing storms to the south and east of the United States will be diminished. This presents an obvious danger to the east coast. In addition, severe winter storm front descending upon the Pacific Northwest from the Gulf of Alaska will also be difficult to monitor. Since weather systems generally move from west to east, day to day weather forecasts will suffer most in west coast States, such as my home State of Washington.

In addition to these concerns there is always the possibility that our current GOES satellite will fail before another satellite is launched. This would leave us with no such satellites in orbit and the effect on forecasting would be catastrophic.

With us today to discuss the situation are two gentlemen from NOAA who were good enough to appear on very short notice. They are Dr. John McElroy, Assistant Administrator for Environmental Satellite, Data, and Information Services; and Dr. Richard Hallgren, Assistant Administrator for Weather Services.

We will also discuss the recent failure of NOAA-8, a polar orbiting weather satellite. Normally, we have two polar orbiters gathering global weather information to supplement that generated by GOES. These satellites are particularly useful for monitoring areas north of the United States that cannot be seen by the other satellites because of the Earth's curvature. The polar orbiters are, therefore, instrumental in long-term forecasts for northern States.

In addition, NOAA-8 was the first and only U.S. satellite with search and rescue capability. We will discuss this today as well.

Senator Heflin, do you have a statement?

OPENING STATEMENT BY SENATOR HEFLIN

Senator HEFLIN. Today we will discuss an issue of vital importance to the Southeast and to the entire country—the question of failing weather satellites and the consequences of that failure for forecasting and for storm warnings. I want to know why our satellites are failing and how we can get the satellite program back on track.

Since east coast satellite failed on Sunday, we have had only one geostationary satellite covering the entire United States. It appears that the National Oceanic and Atmospheric Administration is doing the best it can under present circumstances: it is moving the remaining satellite over the center of the country, so at least the entire continent United States is covered. But this is not a situation that I like.

The problem of hurricane forecasts is of particular concern to me and my fellow citizens in Alabama. Like other parts of the Southeast, Alabama's coast is vulnerable to these disastrous storms. In recent years, timely hurricane warnings from NOAA satellites and forecasters have saved many lives. Future technology, especially the new ground-based radars in the proposed STORM Program, promise even better forecasting in the years ahead. That is why I have cosponsored a Senate resolution in support of the STORM program, and I why I will continue to support innovative, cost-effective technologies to improve weather forecasting and protect lives and property.

For the time being, however, satellites remain our most valuable forecasting tool. Now with the failure of the east coast satellite, the Southeast will be left without full coverage, even if NOAA moves the west coast satellite eastward. My colleagues from other states, both in the Southeast and along the Pacific, have similar concerns about our ability now to detect major storm systems.

The purpose of today's hearing is find out the facts and to discuss our options. There are several things I want to know. I want to know what went wrong with this satellite, and why it apparently failed in the same way as earlier geostationary satellites failed. I want to know why one of our two current polar satellites also has failed. I want to know exactly when NOAA plans to move the remaining satellite eastward and what kind of storm detection and forecasting we will get under these circumstances. I want to know whether the construction and launch of the next geotationary satellite can be accelerated. In general, I want to know why our satellites and our satellite program are having so many problems.

I welcome our witnesses from the National Oceanic and Atmospheric Administration. Gentlemen, I look forward to your testimony.

Senator GORTON. Before we begin, I would like to say that due to scheduling conflicts Senators Stevens, Hollings, and Inouye cannot be here, they are involved in a conference on the appropriations bill for the Departments of Commerce, State, and Justice this morning.

We have received statements and questions from each of them which will be placed in the hearing record, and the record will remain open for at least a week for comments on the part of interested members or other persons.

[The statements follow:]

OPENING STATEMENT BY SENATOR STEVENS

Mr. Chairman. Thank you for the opportunity to express my concern over the recent loss of the Eastern GOES weather satellite.

I have long been an advocate of maintaining a two polar orbiter system for the very exigency now confronting the GOES system. The rationale behind a two polar orbiter system is that if one satellite fails, at least one remains to minimize the data gap. The failure of the eastern GOES satellite illustrates the necessity of having at least a two satellite system to provide weather data. Although the coverage from a single weather satellite leaves a lot to be desired, it is far more attractive than not having any GOES data.

However, a two satellite system without a backup may not cover the needs of the country for weather data. The precarious situation that the eastern GOES satellite's failure has created convinces me that we need to explore the possibility of having a backup GOES satellite in storage or in a dormant orbit. What would happen if the remaining satellite were to fail? The losses in terms of lives and property damage from just one unforeseen hurricane would more than justify the cost of a spare GOES satellite.

The information that GOES system provides for both the east and west coasts is essential, no less for one than the other. The hurricane warnings that the GOES satellite can provide will help reduce the loss of lives and untold millions in property damage. Yet at the same time, the lack of weather data in the Gulf of Alaska created by the need to reposition the remaining satellite increases the risk to the aviation and marine industries in the Pacific—particularly in the Gulf of Alaska and around Hawaii. The storms in these areas are as dangerous as the hurricanes that plague the Eastern United States during this time of the year.

The weather changes very quickly and dramatically along the Alaskan Coast. Calm waters can turn to squall level storms in a matter of minutes. Without the

frequent data on coastal weather patterns, all aviation and maritime activity becomes very hazardous. The loss of the frequent weather information indirectly caused by the satellite failure is even more serious at this time as we are currently in the peak of our fishing season. Our efforts must focus on getting a replacement satellite into position as soon as possible.

I am not alone in this opinion—the reaction and concern shown by my colleagues and NOAA have been the same. Everyone agrees that it is imperative that we do whatever possible to expedite the launch of a replacement satellite without compromising its testing. I have been in touch with NOAA, and have every confidence that they will explore every option to hasten the restoration of the GOES system to full strength.

Thank you.

Opening Statement by Senator Hollings

I regret that a previously-arranged appropriations conference prevents me from attending this morning's hearing. I would like to have been here, for the subject of the hearing—the failure of weather satellites and the impact of that failure on forecasting—concerns me greatly.

I have two main concerns, one immediate and one more long-term.

My immediate concern is to ensure that the Eastern and Gulf states are adequately covered by weather satellites, especially during the upcoming hurricane season. It is imperative that the National Oceanic and Atmospheric Administration provide adequate coverage of the East—as well as the West and Pacific—so that we can continue to detect eastern hurricanes early and provide adequate warning to citizens in their paths. NOAA has committed itself to moving the one remaining geostationary satellite eastward, especially during hurricane season. I am glad to see that commitment.

My longer-term concern deals with the future of NOAA's satellite program. Despite the great dedication and competence of NOAA's satellite professionals, the agency's meteorological satellite program is clearly in trouble. One problem is the lack of backup satellites. We face, and will continue to face, severe budget constraints. But the pros and cons of maintaining backup staellites for situations like today's should be considered.

Related is the equally serious question of satellite reliability. The United States has become very dependent on satellites in recent years, not just for weather forecasting but also communictions, navigation, and many other purposes. Yet over the years many NOAA satellites, especially the geostationary ones, have failed before the end of their scheduled lifetimes. Earlier failures were to be expected, as part of the process of learning about a complex new technology. But recent failures of both GOES–5 and NOAA–8, a polar satellite, show that reliability problems continue. Given the enormous value of these satellites in improving weather forecasts, I want to explore why these failures continue. Is the problems one of design flaws, or contractor performance, or budget policies that force NOAA to keep using older, cheaper configurations? Or are satellites simply inherently complex and unreliable? These are questions I would like to see the Committee explore today and in future hearings.

Even though I cannot attend today's hearing, I welcome our distinguished witnesses. I have great respect for what they and their colleagues have done over the past twenty years to revolutionize weather forecasting and storm warnings. I hope that in the months ahead we can work together to find ways to make our weather forecasting system even better.

Opening Statement by Senator Inouye

The recent failure of the Geostationary satellite "GOES–5" has created a situation that is of great concern to us today. We now have only one geostationary satellite providing sophisticated vital weather information and pictures for the entire United States. This greatly reduces our weather forecasting capabilities, opening potentially dangerous coverage gaps. Clearly, this is a situation which must be addressed promptly and accurately.

In examining this problem, we must look for immediate measures to assure the best possible weather forecasting for the nation during this crisis. We must also look to long-term solutions to this recurring and unacceptable failure of our weather satellites. The information from these satellites is vital to this nation's social and economic welfare. We can stand by and see ths jeopardized no longer.

In the short-run, I would urge NOAA to explore all options available to provide the Pacific region with consistent and reliable weather information while the GOES–WEST satellite is moved east. If these options require additional funding, we should be informed promptly so that we may take the appropriate action to obtain this funding. If agreements with other nations to receive their weather data are necessary, we should also be informed promptly so these avenues can be pursued.

In the long run, it is essential that the troubles we have with our weather satellites are corrected. It is intolerable that multi-million dollar pieces of sophisticated equipment should be rendered useless by the failure of a small lamp time and time again. We must also improve our preparedness for equipment failure by building backup satellites. The recent GOES failure has proven that if we try to cut costs by providing only the minimum protections, it ends up costing us much more in terms of the endangerment of human lives.

I look forward to hearing from the NOAA in the very near future regarding the options and costs involved in providing enhanced weather information during this period of single GOES coverage.

OPENING STATEMENT BY SENATOR RIEGLE

Mr. Chairman, thank you for this opportunity to comment on an issue which is of great importance and interest to Michigan and to the Midwest in general. The loss of the GOES–5 satellite raises a series of questions which must be addressed in a timely fashion, and I am grateful that you have scheduled this hearing on such short notice.

Some of these issues are fairly obvious, such as the cause of the failure and short-term contingency plans to provide emergency coverage during the hurricane season. I understand that NOAA has begun moving GOES–6 to a more easterly location to provide partial replacement for the loss of the GOES–5 platform. I am concerned that this may have an impact on the ability to track severe winter storms which originate in the Gulf of Alaska and ultimately cross the entire American Midwest. Even with this move, which is temporary, the GOES–6 cannot provide the extensive coverage of the Atlantic that was provided by the failed satellite.

I am frankly mystified that we do not possess any backup or replacement systems. In fact, it is my understanding that the GOES–7 is not even scheduled for launching until 1986. This leaves us dependent on one satellite that cannot effectively do the job of two. One cannot help but wonder what the impact of a similar failure of GOES–6 would have on our ability to forecast severe weather and provide storm warnings to the population.

As I stated, I think that these hearings are necessary and should result in a greater understanding of the causes of the failure. I hope that we will be kept fully informed on the status, performance, and expected life of the remaining satellite.

Thank you, again, Mr. Chairman. This is an important hearing, and it serves to graphically illustrate how, in the space of a few short years, we have become critically dependent on our weather satellites for accurate forecasts on a real time basis.

Senator GORTON. At this point, we will begin with Dr. McElroy who can tell us just what has happened with these satellites and what can be done to improve the situation.

STATEMENTS OF DR. JOHN H. McELROY, ASSISTANT ADMINISTRATOR FOR ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICES, AND DR. RICHARD E. HALLGREN, ASSISTANT ADMINISTRATOR FOR WEATHER SERVICES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. MCELROY. Thank you, Senator.

With your permission, we will divide our presentation into three segments: What has happened; why did it happen; and what can we do about it. I will address the first two of these in some detail. Dr. Hallgren will talk about the efforts the Weather Service is currently making to provide support service.

Senator GORTON. We will hear from both of you and then we will ask questions of both of you.

Dr. McElroy. Yes, sir, thank you.

First of all, with regard to what happened, let's start with the polar orbiting situation because that is the simpler of the two to address and it has the least effect on our current services.

We lost the NOAA-8 spacecraft, which is the morning spacecraft that we have, of our two polar orbiting constellations. That satellite is currently being replaced by the NOAA-6 satellite, which is slightly degraded but is providing quite usable service. The afternoon satellite, NOAA-7, is still providing, again slightly degraded, but entirely usable service, and NOAA-7 will be replaced in November of this year.

The NOAA-8 failure, although it happened approximately 10 months prematurely due basically to a random parts failure, has not in any way impacted the service we provide, aside from the interruption of the search and rescue, which is obviously of great concern to us.

The NOAA-8 failure, I might point out, is unique from the point of view that all of the other recent polar orbiting spacecraft have lasted well beyond their expected design lifetime. It is the sort of failure which catches us every now and then, but is not an undue impact in any way.

With regard to the GOES failure, this is far more serious, obviously, and the one that is causing us the greatest concern.

In the GOES situation, we have a device which reads out the position of a mirror. This mirror sweeps across the United States, in fact the entire hemisphere, and creates our pictures. The position of the mirror is read out by what is called an optical encoder, that optical encoder requires a very small light beam, that light beam is generated tungsten filament bulb. It is no more complex in many respects as far as its physical principles than the light bulbs in our homes.

The light bulb has a filament which has basically snapped. It has interrupted the light beam. We can no longer create the pictures that that satellite must produce to serve our weather forecasting needs. There was a redundant bulb, but that bulb has also burned out. The combination of these two has disabled the spacecraft for everything except data communication functions.

That, in a very brief form, is what has happened to the spacecraft. Clearly, the difficulty, that we find ourselves in is that we have no immediate replacement for that spacecraft. As you alluded to in your opening statement, we will not be able to replace the spacecraft until 1986.

Why has this happened? I think that the Weather Satellite Program has always been operated on a very economical basis. It has also been operated on the basis of a calculated risk. In some cases, that risk has been larger than we had anticipated. I think that it is only fair for us to acknowledge that such is the situation now with the GOES-East failure.

Senator Gorton. Can I interrupt and ask you to include in your statement here by how much we could accelerate that May 1986 GOES on a crash basis, and how much in addition it would cost us to do so?

Dr. McElroy. Yes, sir. We are not prepared today to provide those figures. We will provide them to you, perhaps, by the middle

of next week. We have a tiger team at Hughes Aircraft Co. who are looking at exactly that issue.

The early answer is that to maintain the technical soundness of the development program, there is not a way to accelerate that program. We have told them that we cannot accept that as anything less than the most excrutiatingly thought-out answer. They are doing that over this upcoming weekend, and they will provide answers to me on Monday. We will try to get those answers back to the committee just as quickly as we possibly can.

[The following information was subsequently received for the record:]

U:S. DEPARTMENT OF COMMERCE,
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION,
Washington, DC, September 24, 1984.

Hon. SLADE GORTON,
Chairman, Subcommittee on Science, Technology, and Space, Committee on Commerce, Science, and Transportation, U.S. Senate, Washington, DC.

DEAR SENATOR GORTON: At the recent Committee hearings, I indicated that it might be possible to improve the delivery schedule of the Geostationary Operational Environmental Satellite (GOES) currently under fabrication, and that I would ask NASA to investigate the feasibility of launching earlier than the May 1986 contractual date. The prime spacecraft contractor, Hughes Aircraft Company, was asked to consider whether they could accelerate the spacecraft delivery schedule without compromising the reliability of the program.

We all believe it is possible that GOES–G can be launched in time to observe the onset of the heavy winter (1985–86) season. You will understand the benefits of this. We have concluded that we should try the accelerated program.

A 4 to 6 month acceleration in the spacecraft delivery can be achieved by a combination of increased shift work, reduced repeat testing, and elimination of some planned slack times during the December 1984 to March 1985 time period.

NOAA and NASA have reviewed the revised GOES–G qualification plan. We are convinced that the accelerated program does not represent a technical nor reliability risk. If problems are found during satellite testing, we will delay until they are solved. Such delays would merely push the launch date out closer to that originally planned in the spring of 1985.

The GOES–G accelerated delivery plan is ambitious and will require dedication and attention to detail by Hughes and by NOAA and NASA. We believe the risk to the new schedule, inherent in this type of program, is necessary if we are to minimize the period of reduced GOES coverage and have, therefore, directed Hughes to proceed on the improved schedule. While the costs of moving faster are not yet firmly established, they appear to fall within the amount of award-fee returned to the Government after the GOES–5 failure, so no additional authorization appears necessary for this action.

Sincerely yours,

JOHN H. MCELROY,
Assistant Administrator for Environmental Satellite, Data, and Information Services.

Senator GORTON. Thank you.

Senator HEFLIN. Let me interrupt.

Dr. MCELROY. Yes, sir.

Senator HEFLIN. I apologize for not being here at the beginning, but I have to divide time between other committee assignments. In the Judiciary Committee, we have the constitutional amendment to balance the budget coming up, which I am very much interested in. If you don't mind, I would like to ask some questions up front.

Obviously, in the arranging of weather satellites, we went with two. We had one on the west coast and one on the east coast. We had none in reserve to be used, which may have been a mistake. I am not pointing the finger at anybody, but obviously it was pretty poor planning in the sense that what occurred was not anticipated.

Now it will take this long period of time to get a new one built. What is the possibility of the other satellites that we have being

used temporarily? Not just one satellite but a number of satellites that could be fitted and that could provide, maybe not as completely, but nevertheless could provide information like a weather satellite, particularly in the event that a hurricane or some other tremendous weather devastating disaster were looming?

What is the possibility of some action, using military satellites or other type of satellites, that can give us warnings of these storms?

I happen to live in a State that borders on the Gulf of Mexico, and we have had some horrible hurricanes. We had the horrible Hurricane Camille over in Biloxi, MS; it brought devastation and many lives were lost. Then we had the Hurricane Frederick, and as a result of the early warning that came from the use of satellites and other methods, law enforcement officers and other officials were able to evacuate most of the coast town and there were no fatalities as a result. A comparison between Camille on the one hand and Frederick on the other hand show that because of the early warnings, we were able to save a great number of lives.

Here we are in a situation where obviously we need two weather satellites. In the meantime, until we can get two, are there possibilities of using other types of satellites, not just one but numerous ones if they have much narrower areas where they could be used, that could help with warnings?

We have the technology. We know today that we have a new system known as STORM that eventually will be able to give advance warnings of a tornado going down into an area as small as a square mile, and identifying where it might touch down, with the use of computers, satellites, and others technologies. According to my information, before we can get it implemented and in place, it will take a long period of time.

It is presently on the drawing-board, but many of us are moving to try to get that expedited. Senator Gorton has had hearings on this. I think that he and I together are pushing bills on this. All of this is a serious problem regarding warnings and the saving of human life.

We are talking about a replacement right now that is at least 2 years off. Are there other methods by which we can give early warnings and save human life in the event that hurricanes occur?

Dr. MCELROY. Yes, sir, there certainly are. Let me open by providing two very quick answers, and then turn the floor over to Dr. Hallgren who will elaborate in more depth on the hurricane forecasting.

With regard to one point you made: Is it possible to outfit other satellites? No, sir, we do not believe it is feasible within this time period to provide any useful help.

Is it possible to provide other satellite data, however, that will be useful in doing the hurricane forecasting? Yes, indeed. Both the GOES-West satellite in its new position over the center of the United States, and the polar orbiting satellites, both military and civil, will all provide data which is useful and will meet the principal needs of hurricane forecasting.

Dr. Hallgren will provide further information.

Dr. HALLGREN. Yes, as John indicated, we can make use of the polar orbiting meteorological satellite imagery quite extensively in

at least augmenting somewhat the capability to observe in the Atlantic and in the Pacific.

First of all, let me just say that we have made the decision to move the geostationary satellite that is in good shape over to 98°. If you look at the coverage you get with the satellite placed at 98°, you find that, first of all, the continental United States will be well observed after it is in position.

Senator HEFLIN. Obviously, the decision was made in the beginning that you needed two.

Dr. HALLGREN. Yes.

Senator HEFLIN. Now, you have one. So you are having one to do the work of two. Obviously, one can't do the work of two.

Dr. HALLGREN. That is true.

Senator HEFLIN. All right.

Dr. HALLGREN. That is true, and I was just trying to tell you so that then I can tell you what areas we would have to try and augment the best we can. Also, by having it positioned at 98°, not only is it observing the continental United States well, and that is particularly important for the tornadoes, flash floods, and severe thunder storms that we have to contend with during the summer, but it also gives coverage out into the Atlantic so that on the average we will be seeing storms 3 to 4 days in advance with that particular satellite for the coastal waters of the continental United States. With regard to Puerto Rico, the advanced coverage is more like 1 to 2 days. It is more restricted.

We would be augmenting the information, though, for the hurricanes moving out more into the eastern Atlantic by using the polar orbiting meteorological satellites, and then also getting information from the geostationary meteorological satellite that is over the European area.

So we will be making use of all three arrangements to try and get as much information as we can. It will not be, of course, as good as having the geostationary satellite appropriately placed over the Atlantic.

I might mention also that there are hurricanes in the Pacific. These hurricanes most frequently form off the west coast of Mexico and the countries south of there down to Panama. The ones that affect the Western part of the United States form in that region, and most frequently come up along the California coast, and move inland in Mexico and cause flooding in our Southwestern States. This area will also be under excellent observation with the geostationary satellite being at 98°.

As you go out to the West, over the Pacific and out toward Hawaii, the coverage will be very weak. I believe that John McElroy can use, at a much reduced level of capability, an old geostationary satellite that gives us images during the day. We will also be making maximum use of all of the U.S. polar orbiting meteorological satellites in that area. We will also, as soon as the Japanese satellite is launched this fall, be making use of that data.

The most tricky area in that is very near and west of Hawaii where the only information we will be able to get, other than the information from ships, is from the polar orbitting meteorological satellite which is far less frequent, of course, than the geostationary satellites.

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Those are the ways in which we will be augmenting with regard to hurricanes. I have not covered the area up in the North Pacific, of course.

Senator GORTON. Why don't you continue with your presentation.

Dr. MCELROY. The second issue that we need to address is: How did we get ourselves in this situation?

I think, to our discredit, there was overoptimism in projecting the life of the spacecraft. I think, although that is certainly a criticism which is entirely legitimate, the projections of the life of the spacecraft were made by the best experts in the country. Their assessment of how long the spacecraft would last, projection of a 5-year lifetime, for example, was made with the full support of the best minds in U.S. industry.

For example, in setting up the contractual arrangements with the Hughes Aircraft Co., they quite willingly agreed to a progress payment schedule which put some $3 million at risk in the sixth and seventh year of the expected lifetime of the spacecraft. The companies felt confident in doing this. They have been bitten, if you will, by the unexpected failures in a couple of components.

Senator GORTON. That is to say that Hughes Aircraft will not be paid as much for the satellite because of its early failure than it would have been otherwise?

Dr. MCELROY. That is most certainly true, sir. They are going to take a very heavy penalty over this.

The thing which might have been done some years in the past would have been, perhaps, we should have bought more satellites and had more in the queue. As I said earlier, that is a calculated risk which was taken, and it now has proven to be an excessive risk.

We are now looking at initiatives within the budget process, I can't say exactly how they will come forward, which will allow us to buy a larger quantity of satellites so as to keep the queue better filled.

Senator GORTON. Before the failure of this satellite, the schedule for the next one to be launched is May 1986.

Dr. MCELROY. Yes, sir.

Senator GORTON. What future schedule for additional satellites beyond the May 1986, satellite were in place?

Dr. MCELROY. Let's go through the various schedules very briefly.

We had purchased, in one buy from the Hughes Aircraft Co., this most recent series of three, the last of which is the GOES-6 spacecraft which is the last working spacecraft in orbit. We had begun negotiations over the next series of satellites. We were fairly deliberate in going through those negotiations because of the rapid increase in cost of the spacecraft that we saw in the GOES G&H procurement. Having gone through that rather deliberate process that led to the early spring 1986 date.

We immediately, then, began the planning for the follow-on spacecraft beyond that. So after the two are delivered in 1986, the next delivery is subject to ongoing contractual negotiations.

Senator GORTON. Two are to be delivered in 1986?

Dr. MCELROY. Yes, sir.

Senator GORTON. In May 1986, and what other month?

Dr. McELROY. August of 1986 is the current schedule.

The negotiations are underway at this moment with a number of firms. This is under a Source Evaluation Board process, so I cannot elaborate on those negotiations at the moment, but those negotiations will lead to what we call GOES-Next. The GOES-Next delivery is dependent upon exactly which firm is selected, and the particular schedule that they propose.

Senator GORTON. There is more than one potential contractor?

Dr. McELROY. Yes, sir, prior to the start of the negotiations, we had expressions of interest from Hughes, from RCA, and from Ford Aerospace. I am not privy to exactly what proposals have been received by NASA who is our agent for that at this moment.

The schedule is likely to be in 1989 to 1990 delivery for those spacecraft. So the GOES-G&H spacecraft that will be delivered in 1986 must then survive through 1990, roughly. We believe that is a realistic schedule, and that the lifetime of those spacecraft should be entirely satisfactory to meet that.

Throughout the development, procurement, and life testing, if you will, in orbit of the spacecraft, we have made a number of modifications to improve reliability. We think we now see quite clearly the way to 4 or 5 year lifetime. I would understand if you say, "I don't share your optimism." Certainly, on our track record, we cannot give you great confidence.

But we have gone through the problem of darkening bulb first in this encoder, and the problem was solved. That led to a little longer life, at which point we found that lubrication buildup on the shaft can block the motion of the mirror. We solved that problem and moved on. Now we find the filament in the bulb burning out at a somewhat later period in time.

We are going to a much more redundant system which will get us by that problem. Predicated on the more than 3-year lifetime we experienced with the GOES-East spacecraft, we think that four years is quite comfortable.

Senator GORTON. I gather that there is no possibility of changing the orbit of the failed satellites of either type in orbit so that they could be intercepted by the space shuttle and repaired in space, or returned to Earth?

Dr. McELROY. No, you are absolutely right, Senator, this would require a supply of fuel on board the spacecraft or a rocket engine of some sort that is not there. We cannot deorbit the spacecraft down to a sufficiently low altitude for the space shuttle to reach it.

Senator HEFLIN. I understand that NASA is working on things of that sort. I don't know how far along they have gotten with it.

I know that at Marshall Space Flight Center at Huntsville, AL, in my State, there is ongoing research on how to bring something in geostationary orbit down into lower Earth orbit. Have you explored this with NASA as to whether or not it might be possible?

Dr. McELROY. Yes, sir, we certainly have. We are following with great interest all of the NASA activities in the space station. In fact, this morning I have one of my people attending one of their planning meetings on the so-called space platform. We are most interested in the 1990 period for the space station and using all of the servicing capabilities that might be available to us to reduce cost.

Senator HEFLIN. One thing on the use of only one satellite. Historically, the hurricanes that eventually hit the gulf coast of America, hit my area, generally have followed a sequence of originating somewhere off the west coast of Africa and then moving across the Atlantic Ocean into the Gulf of Mexico, and the up the gulf coast and hitting land there.

I notice that this one satellite that you have does not cover that area west of Africa where most of these have historically originated. Is there any way that some activity could be focused on that area to determine whether or not a hurricane might be forming?

Dr. MCELROY. Yes, sir. Let me address the satellite issue first, and then I will let Dr. Hallgren speak in more detail

There are two charts before you, I believe, one of which is this chart which shows two rather darkly outlined diagrams, and one which shows three bull's eyes with 98 degrees in the center. If you, first of all, look at this diagram, which does not show the European satellite, you certainly come away with that impression.

If, however, then you look at the diagram labeled "METEOSAT 0 degrees west," which is the bull's eye just to the right, that is the coverage by the European satellite. As you see, it does indeed extend out beyond the western tip of Africa into this so-called breeding ground for hurricanes. So there is some coverage which is available. I don't mean to paint the picture excessively favorably, but there is indeed some coverage down in that region.

Senator GORTON. In interpreting these charts, which we will include in the record, how do we go about doing that? Is the primary coverage that which is in white, without the crossed lines? To what extent is there coverage within the much broader ovals with the cross-hatched lines on it?

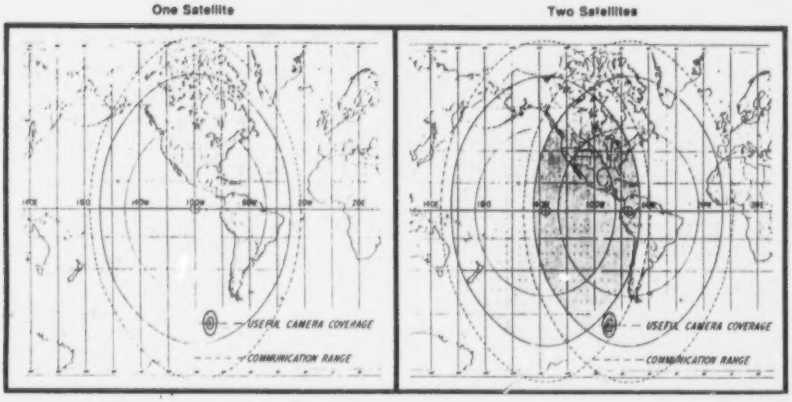
Dr. MCELROY. For talking purposes, we had to bring available charts today, Senator. Let me tell you what these charts really represent. These are the coverage circles or the elevation angles from ground stations. If you took about the third ring outwards, and each of those circles, the third and fourth ring, that is the primary good data area for the satellite.

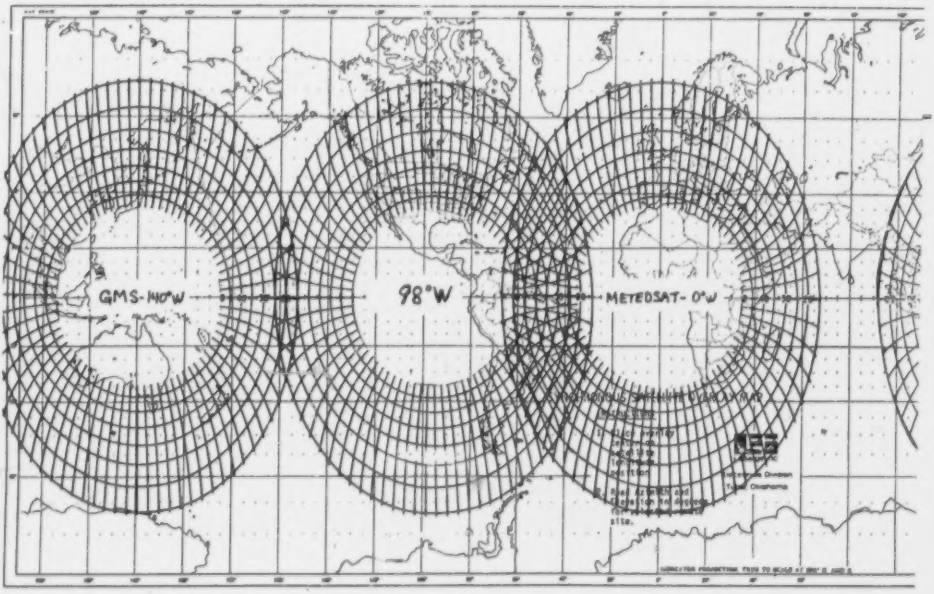
As you go beyond that, the data in a rather graceful way degrades, and by the time you get to the outer rings, you are sort of getting marginally useful data. But our weather forecasters will take whatever they can get to give them clues as to what is going on. So it is basically a gradual degradation of quality of data.

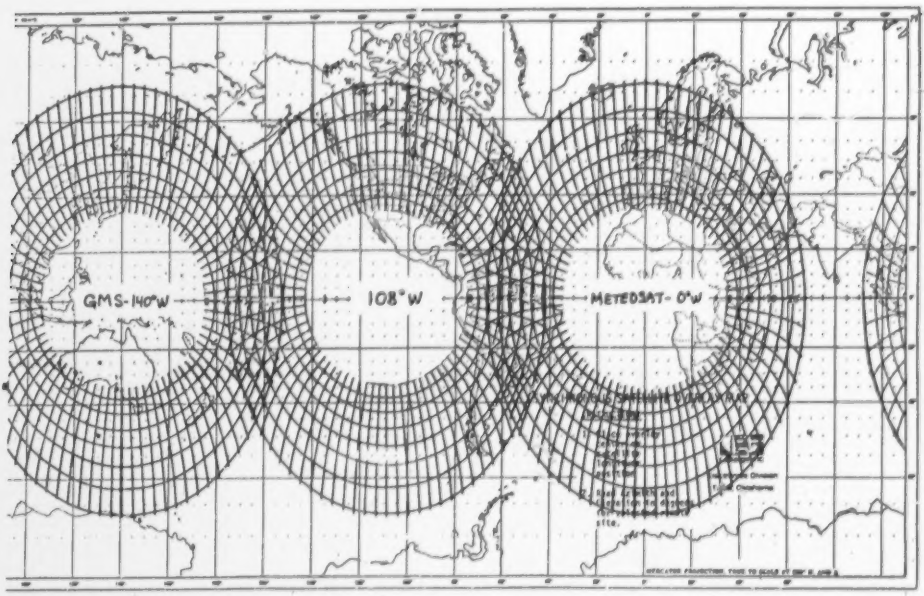
We will be preparing much better diagrams than this as we have more time during the day, as a matter of fact.

[The charts follow:]

GOES Geographic Coverage







Senator GORTON. Excuse me. Senator Heflin may have to leave.

Senator HEFLIN. I have to go to the other meeting. We may have to have a cloture vote in the Judiciary Committee, and they are hollering for me to come.

One more question: You have the variances of the Earth between winter and summer. There is some tilting, some closeness to the Sun, and some effects because of seasons.

Dr. MCELROY. Yes.

Senator HEFLIN. We are entering into a fall area not too distant from now. Will your remedial efforts be designed to account for the weather changes that have historically occurred during changes of season?

As we obviously know, as you change from one season to another, you have rather disastrous seasonal weather conditions, such as tornadoes and hurricanes. Are you accommodating as best as you can to allow for these changes of seasons and for the winter that is coming on?

Dr. MCELROY. Yes, sir, we certainly are.

The choice of 98° W. longitude as the position that we are moving to and will arrive there as of August 21, was made with the recognition that this is, of course, the hurricane season. We will keep it at position until November 30, and then we will begin to move it in anticipation of the winter storms off the west coast, and we will move it out to 108° W. longitude to better provide that coverage.

Senator HEFLIN. Thank you.

Senator GORTON. Thank you, Senator Heflin.

I am sorry. We have interrupted you in your opening statement which simply indicates our great interest in this subject. Have each of you completed what you were going to discuss, or would you like to go ahead?

Dr. MCELROY. I think that Dr. Hallgren may wish to summarize some of the other activities which are going on.

Senator GORTON. Fine.

Dr. HALLGREN. I will try to be very brief.

As I mentioned in response to one of the questions, the situation over the front of the United States after we get the satellite located and moved to 98 degrees will be quite satisfactory, assuming we don't have a failure of the good satellite that we have today.

Right today, in talking to the National Hurricane Center, they are operating with substantially degraded data because the satellite is way out, 135° W. and just starting to move, and the imageries are degraded somewhat as the satellite moves.

Senator GORTON. Again, can I interrupt you? Is it your plan, as reflected in these charts which you have given to us, to move that single GOES satellite to 98° W., and then at some point or another to shift it back to 108° W.?

Dr. HALLGREN. Right, that is after the hurricane season is over, as John McElroy said. The official termination of the hurricane season is the end of November. At that time, we will move the satellite from 98 degrees to 108 degrees.

Senator GORTON. Do you have enough fuel on that satellite so that that shift between 98 and 108 degrees can effectively be carried out in each of the years until we have another satellite?

Dr. MCELROY. Yes.

Dr. HALLGREN. You didn't hear John's answer, but the answer is yes.

Dr. MCELROY. Yes, sir.

Senator GORTON. Please go ahead.

Dr. HALLGREN. There are some number of days here while the satellite is being moved during which our coverage east of the Mississippi is not good at all, and we are having to go into a manual mode of determining the exact geographical position of the cloud systems. I assure you that the people at the National Severe Storm Forecast Center are doing a good job in handling that.

I mentioned that on the hurricanes for this fall, along the east coast, I think once we have the satellite in position, we will have good coverage, 3 to 4 days advance information, and tracking capability before they would hit the mainland coast. A little bit less, 1 or 2 days, for Puerto Rico, but we will backing up to the East with the U.S. polar orbiting satellites and the European geostationary satellite that John just referred to.

In fact, this morning, talking to the people at the National Hurricane Center, as Senator Heflin indicated, the storms do start on occasions right near the African coast, we could see on METEOSAT this morning that there is a disturbance there, but it is not a hurricane. We are watching it through that capability along with the polar orbiting meteorological satellite.

I also assure you that we will not hesitate to use aircraft reconnaissance to an even greater extent than we normally do during the fall, and we will be doing that both in the Atlantic and the Pacific. We are examining ways in which we can assure that we get reconnaissance into hurricanes that may hit any part of the United States, whether it is the continental United States, Puerto Rico, or Hawaii.

With regard to the North Pacific and the Gulf of Alaska, the difficulties are obviously greater. The satellite, after it is positioned

on August 21 at 98° W., we will not have coverage in the Gulf of Alaska and most of the area to the northwest of Washington and Oregon.

Senator GORTON. How much better will that coverage be after the hurricane season is over and it moves back to 108 degrees?

Dr. HALLGREN. Somewhat better, but it will not extend into the far reaches of the Gulf of Alaska.

What we are doing there, we are trying to make maximum use of the polar orbiting meteorological satellite because with the orbital characteristics, we get more frequent coverage in the northern part, at the higher latitudes. We will be using the imagery from that very extensively.

It is, obviously, not as good as having the geostationary satellite because you would not get full coverage like over the Gulf of Alaska from the polar orbiting meteorological satellites but every 2, 3 or 4 hours. We will be trying to make sure that we process that data in the best and most useful way we can to enhance the observational data base.

We will also be examining whether we should make more extensive use of aircraft reconnaissance in that area during this period.

Senator GORTON. You have completed your opening statements.

Dr. MCELROY. Yes.

Senator GORTON. Thank you.

Dr. McElroy, I think I understand the schedule that you have set for us, but let summarize what I believe it is that you have said about the future construction, delivery, and orbiting of GOES satellites.

At the present time, you have a contract with Hughes Aircraft for the delivery of satellites which would be scheduled to go in orbit in May and August 1986.

Dr. MCELROY. Yes, sir.

Senator GORTON. You have inquired as to whether or not delivery dates can be accelerated, I take it, within the present contract cost, or even with some additional contract cost.

Dr. MCELROY. Yes, sir.

Senator GORTON. The preliminary answer is, no, but that you are following up on that with the hope that you will have that information by early next week.

Dr. MCELROY. Yes, sir.

Senator GORTON. I hope that you will share that information as promptly early next week as you can as one possible opportunity to do something about that here will pass by fairly quickly next week.

Dr. MCELROY. Right.

Senator GORTON. Second, you are in the process of negotiating with at least three potential contractors for two additional satellites with roughly estimated delivery dates of 1989 or 1990.

Dr. MCELROY. Yes, sir.

Senator GORTON. Am I right that it is two additional such satellites?

Dr. MCELROY. It is three additional satellites.

Senator GORTON. Three additional such satellites.

Presumably, if we were to decide that the deliveries of those satellites were to be accomplished on an emergency basis, we could somewhat accelerate those 1989 or 1990 deliveries.

Dr. McELROY. There are some possibilities.

One additional fact, which I mentioned only in passing, we are also investigating whether that procurement should be expanded beyond three spacecraft to a total of five. We have requested that the contractors provide us an option which provides us the cost of doing so.

Senator GORTON. When are we likely to have information on which we can make an intelligent decision and act here in the Congress with respect to that next procurement?

Dr. McELROY. The next procurement will not occur until well into fiscal year 1985. So it would be probably in the second session of the upcoming Congress in all likelihood.

Senator GORTON. I understand that several of the previous GOES satellites experienced the failure of the encoder lamps just as GOES–5 has. Does the current one that we are talking about, that we have in orbit, GOES–6, have more backup lamps or a different system that gives us hope that this failure will not take place with respect to it?

Dr. McELROY. Yes, sir. We have basically doubled the redundancy in the encoder system.

Senator GORTON. believe that in answer to one of Senator Heflin's questions, you spoke about the way in which life expectancy for these satellite is determined. You said that you used the best outside experts you could find. Has the actual experience provided you with better information for future estimates, and as a result are your future life estimates lower, or has the knowledge of the actual failures resulted in your changing specifications to the extent that you are more confident that we can get 5 or 6 years out of the next series of satellites?

Dr. McELROY. I believe the latter is the correct view of that. Certainly, it has explained to us why we have had the premature failures.

If you look, however, at the experience with communication satellites, if you look at the changes which are going to be done in improving the redundancy of the sensing systems onboard the spacecraft, we see no reason why a 5- to 7-year life time is not a realistically attainable goal.

Senator GORTON. We certainly hope that it is the case.

Dr. McELROY. Along these lines, I think there is one comment that might be appropriate.

There is obviously concern that has been expressed to me: Has our contractor laid down on the job, if you will? Has there been some malfeasance on the part of our contractors?

I really would hate to see that sort of a characterization of this problem being made. Everyone operated, I think, with the best available knowledge. There were certainly no facts hidden in any of that. I think that intelligent decisions were made based on the knowledge that was available. Some of those decisions have proven to be bad ones. However, I believe that that is the normal thing which happens in complex engineering jobs.

If you look at the performance of the contractors that we have working for us, whether it is Hughes, RCA, ITT, or in the past Ford Aerospace, in each case they have been extraordinarily talented engineering teams that have been put together. I see no hint

at any point that there was something which was really stupid that was done.

Senator GORTON. At this point, it is obviously convenient to argue that NOAA should have stockpiled satellites to avoid gaps such as this. If you were buying three or four at a given time, they should have been built contemporaneously so that they could be launched into orbit promptly.

On the other hand, it is quite obvious that we are on the cutting edge of technology in this field. Each problem we have teaches us something about what we should do in the next series or even the next item in the same series.

How would you evaluate the relative values of stockpiling against stringing out the construction in an attempt to make improvements?

Dr. MCELROY. When one buys a large number of satellites at once, you gain certain economies of scale in that procurement. Your per unit cost is certainly going to be lower. Having built them, however, en mass then leads us to a potential for changes that have to be made in those spacecraft later on as you learn things from the early flights.

In general, we expect that the large procurement savings will outweigh those later changes so the net effect is one of an advantage to the taxpayer.

Senator GORTON. You spoke very briefly, at the beginning of your statement, about the loss of search and rescue capability by reason of the failure of NOAA-8. With all of the recent talk about peaceful uses of space and cooperation with the Soviet Union, not very many people know much about that SARSAT program.

Can you describe what it is; what the impact of the failure with NOAA-8 was, and how we will deal with that problem in the future?

Dr. MCELROY. Yes, sir.

It happens that some 5 years ago, I was Director of the Communications and Information Systems Program for NASA, and I was in charge of that program, So I have a soft place in my heart for it.

The search and rescue program began in approximately 1976 through a cooperative activity that started off between the United States on the one side, and France and Canada on the other side.

France had already developed a system called ARGOS, which was a data collection and platform location system, and it was obvious that that system had certain capabilities in a search and rescue scenario. Canada has a large search and rescue problem with its huge northland region and, therefore, had a strong motivation to enter into such a program as well.

The original agreement was that the United States would provide space on the weather satellites, Canada would provide a receiver and transmitter to go onboard for the search and rescue system, and France would provide the processor that goes with that.

The way the system operates is that a crashed aircraft or a ship in distress will radiate a very weak distress signal. It is the equipment that is standard on ships and aircraft; it is not especially designed for space or use with a satellite, so there is no added burden on the people. That signal gets radiated up to the spacecraft as it

comes by. The spacecraft then relays it to a local user terminal, which then sends a signal to a rescue coordination center, and the rescue forces are dispatched.

Shortly after the beginning of the ARGOS program, the Soviet Union approached the United States and expressed interest in joining. Obviously, there are concerns about technology transfer in any such arrangement, so a very, very efficient way was achieved to both limit the tech transfer on the one hand, but attain cooperation on the other. That method was to create an interoperable system by exchanging specifications.

The Soviets, then, provide a totally interoperable system, which in some cases has greater capability than the U.S. system, in that it will read out directly to our users, whereas we cannot do that for them.

The Soviet system now has three spacecraft in orbit with search and rescue capability. Obviously, the more spacecraft that are up there, the less waiting time there is in a disaster between the time of the crash or the accident and the time that the rescue force arrives. This clearly relates to the potential mortality of the victims.

The system has now been in place for going on 2 years. We have more than 230 rescues directly attributable to the satellite system. This year, we are coming to a close on the experimental phase of that activity, and I will be traveling to Leningrad in the last week of October to negotiate with the Soviets on the continuation on an operational basis.

Senator GORTON. Thank you.

Dr. Hallgren, let's start by looking at a worst case scenario which would be a failure of GOES-6 before the launch of another satellite. To what degree would that adversely affect our weather forecasting activities?

Dr. HALLGREN. Very, very substantially, because the GOES satellite and the data from the GOES satellite, and particularly the images play a major role in our severe weather and flood forecasting. If GOES-6 were to fail, obviously, we would continue to make the full use of all of the other data, including the radar data, but I would say that we would have a very substantially degraded warning capability, and particularly a watch capability over the United States. So we are all hoping that this doesn't happen.

Senator GORTON. Am I correct in my assumption that inland forecasting depends to a very considerable extent on weather conditions and the movement of those conditions in surrounding areas, while coastal weather, particularly on the west coast, is more difficult to predict because it comes from the ocean?

If I am correct in that assumption, over the period of the 2 years until we get a new satellite, isn't it likely to be west coast forecasting which suffers the most?

Dr. HALLGREN. Yes, in terms of the every day forecast because, as you indicated in your statement, the weather moves west to east, except in the tropics where it moves more east to west. Off of the western coast of the United States, the storms are coming in from the Pacific, and the geostationary satellite is an important observing tool from those oceanic areas where we have much more limited data. So it would lead to a substantial degradation, I would think, in the forecast of major storms striking the west coast.

Senator GORTON. It is to try to compensate for that to a certain degree at least that you will be moving the satellite back and forth between 98 and 108° West.

Dr. HALLGREN. That partially compensates for it, and also trying, as I indicated, to make maximum use of the polar orbiting meteorological satellite data.

Senator GORTON. Senator Heflin has already asked questions about it and expressed his concerns over the effect of the loss of GOES-5 on the prediction of hurricanes. Is there a serious risk that a totally unexpected hurricane can strike the South or East?

At least once you have accomplished this movement of 98° West, would you describe our ability to observe storms as remaining adequate?

Dr. HALLGREN. Yes, adequate for the continental United States. We are going to be working hardest to augment for the area east of Puerto Rico.

Senator GORTON. What would your opinion be on that question if we lost GOES-6?

Dr. HALLGREN. We would be in very serious trouble because the way we operate today is that we use the GOES satellite in just innumerable ways, not only locating where there is the slightest sign of a tropical storm developing, right through to its tracking capability, and very selectively use the aircraft reconnaissance to augment the satellite imagery. We would then not know when storms are developing in the early stage anywhere near as well, and we would have to use extensive aircraft reconnaissance to even plug it somewhat. Of course, we would continue to use the polar orbiting meteorological satellites.

Can I follow through a little bit on that?

Senator GORTON. Sure.

Senator HEFLIN. I am not an expert on this and a lot of questions may be out of ignorance, but I am trying to probe.

Doesn't the early detection of the initial formation of a hurricane, and the information that is gained at that stage is give you better indications of the type of growth that will follow than will detection after it is formed?

For example, you can probably start predicting the future of a certain hurricane if you are able to see it and to determine its formation off the West Coast of Africa and to follow it as it moves, in order to get a long run idea of the direction it is going, rather than picking it up later.

In other words, it is sort of like predicting what a 21-year-old is going to look like if you are able to determine its form from its embryonic stage and from its early birth, rather than picking up after the child is 4 or 5 years old. That early period can give you a lot of information that you can't later acquire. Is that correct or not?

Dr. HALLGREN. I would answer this way. There may be some information in that, but it is very small. That is not one that concerns me. The main thing that concerns me is to see it in the early development, when it first develops, so that we have plenty of time to track it beforehand. That is very helpful in some of the statistical models we run as to determine where it is going to go in the future.

As I indicated, there is a small disturbance, it is not a hurricane, it is not a tropical storm, this morning right off the coast of Africa. We are seeing it on the European meteorological satellite, as well as our polar orbiting meteorological satellite.

I am not concerned about that point of having a lot of information other than its location whenever you see it in an embryonic form when it is first developing.

I might also add that, of course, we also have to worry about the shipping and the ships, so we try to track these storms for that purpose as well, so we get the best warnings out to the ships that are traveling in both the Atlantic and the Pacific. So at all times, it is important to know where they are, what their intensity is, and what direction they are going, not just, of course, when they are going to strike the mainland.

Senator HEFLIN. Let's say that a military aircraft is going to travel from the United States to Africa, to the Mid-East, to the West Indies, to Guatemala, or to various other places, with all of the types of military aircraft that we have.

Let me ask you this. Are there foreign countries that either have satellites or that have some type of compensating devices or systems that we could arrange to borrow or lease full time, or part time, which could help us with aircraft until a replacement satellite can be placed in geostationary or polar orbit?

Dr. HALLGREN. I will leave part of that question to John McElroy, but let me just say that I also serve as the permanent representative of the United States to the World Meteorological Organization and, of course, a major aspect of that organization is to ensure that observations are taken around the world in a standard way so that we can all use them and ensure that the communications are in place so that each country gets the data from around the world quickly.

We exchange this data freely, at no cost. Therefore, any data that they have, and as we were indicating in our conversations here, the European satellite, we get the data from them. When the new Japanese satellite goes up, we will get the data from that satellite. So there is a full sharing.

Now, as to whether there is some facility that might be available, I don't know of any, but maybe John can answer that.

Dr. MCELROY. There are basically three foreign satellite systems in addition to our own of this variety, not counting the Soviet meteor system.

Senator HEFLIN. I didn't understand you.

Dr. MCELROY. The Soviets have a low altitude system, so I am going to exclude the Soviet system from the discussion.

Senator HEFLIN. They have a low altitude system?

Dr. MCELROY. Yes, sir. They are like our polar orbiters, but in a somewhat different orbit. It is analogous, however, to our polar orbiters.

The three foreign systems are the Indian system, Insat, which is built for them by Ford Aerospace; the European system, Meteosat, which is built in Europe; and the Japanese system, the GMS system, which was originally built by Hughes and is now gradually being built more and more by the Japanese.

These three systems are all coming on line and to an operational stage, and none of them really have additional spacecraft available that they could provide to us for our near-term use. Over the longer term, we probably don't have a problem where that enters in. I think that there is no plausible way that we can get from them a spacecraft that we could use to cover this next 2-year period.

Senator GORTON. Dr. Hallgren, most of us who are lay persons in this respect get the impression from television that our forecasts come almost exclusively from satellite data. To what extent is that correct, and to what extent is that a simplification?

Dr. HALLGREN. The satellite systems are very, very important, but they are an observing tool. They provide a substantial amount of the observations on a global basis, but you do have to have all of the other observing capability, and then you have to have your computing centers where you ingest all that data and take the physics of the atmosphere, have it in a model and produce forecasts, as well as when it gets down to the preparation of warnings. Those have to be prepared at the local level because there is a very short period of time, and you use all kinds of information. You are using radar information, you are using storm spotters, as well as the satellites and all other meteorological information. So, it varies from one thing to another, depending on what you are trying to forecast. But, they are a very important part of the observing system now.

Senator GORTON. To the extent that when we watch weather forecasts on television, we are actually very frequently given satellite pictures, to what extent are we going to lose that ability to see those satellite pictures on television at the edges in a place such as Seattle particularly while the satellite is at 98° West? Will we simply not have that ability for these next few months at all?

Dr. HALLGREN. When it is at 98 degrees, you will have coverage. This one here, with the shaded area of the map on the left, will give you the area that you will be able to see.

Senator GORTON. Which one, the inside line or the outside gray line? The inside one seems to go right through Puget Sound.

Dr. HALLGREN. I guess the outside one, but they are highly degraded out near the edge of that. You will at least be able to see good, high quality images on your television screen and the forecasters will also, in the station, over the entire United States, and a portion of the Atlantic and a portion of the Pacific.

Dr. MCELROY. The inside line on that, Senator, is the quantitative determination of wind speed from cloud motion. That quantitative measure degrades somewhat, but as far as the actual image quality that would be displayed on the TV, the full gray area would be displayed there.

Senator GORTON. Could you describe once more for me the difference in weather forecasting functions between the GOES satellites and the NOAA satellites. Again, especially at the outer edge of the effective GOES satellite, how much are we still getting from the NOAA satellite as against GOES?

Dr. HALLGREN. It varies with latitude, of course. With the polar orbit, the image information is once every orbit, or 100 minutes, roughly, 14 times a day, in the very northern latitude Down at the

equator, the passes are far less frequent and they are more like every 6 hours that you would get a pass, half of them during daylight hours and half of them during nighttime. Whereas on the GOES satellite you can get them every 30 minutes or even less for selected areas.

Senator GORTON. Is there any functional difference between the two kinds of satellites from the point of view of the pictures they take and the information they develop as against how frequently that information comes in?

Are they taking the same kind of things with the same kind of cameras, from the same altitude?

Dr. HALLGREN. They are at different altitudes. Most important, you see, you can see the storms much more clearly and much more definitively when you have the frequent observations. We have the capability of cycling and looking at 10 pictures in sequence that have been taken at half-hour intervals, but the forecasters look at them over a period of 1 minute and they can see how major thunderstorms are developing, or a major low system with a large amount of clouds is expanding. Also, as John McElroy just indicated, you can actually track the clouds and determine wind directions from that.

So it is much more useful information. Whereas in the case of the other, it is never from the same place. The sweep that you are looking at is of a different perspective than at subsequent times. It is a much more complex process. The GOES imagery is much, much more important in trying to handle the short-range forecasting problem, particularly in the severe weather and flooding areas.

I might add, in the case of the NOAA polar orbiting satellites, there are temperature sounding devices and moisture sounding devices on those, and they are absolutely important over the ocean area. When we have a normal operation, we are using the polar orbiting meteorological satellite imagery only to a small degree except at very high latitudes. We are principally using the satellite temperature and moisture sounding capability of the NOAA polar orbiting satellites.

Senator GORTON. What relationship is there between NOAA and the Department of Defense? Does the loss of this satellite have any impact on the national security? On the other hand, can any Defense Department satellite be used to supplement the information which we receive?

Dr. MCELROY. The Defense Department uses our data as well as their own data. So there are analogous and limitations which they will feel by the absence of this satellite. They are modest ones because they do have their defense meteorological satellite program which is specifically tailored for their uses and needs, and that is their principal source of data.

One thing that it does limit is that we have on the carrier battle fleets, for example, some readout capability of the GOES system, so some of the ocean areas, as you can see from the charts, will not be covered.

With regard to the relationship, as far as the use on the civil side of the DMSP data, Defense Meteorological Satellite Program, the DMSP data is available, for example, in Hawaii, in Alaska. We rou-

tinely have that coming into the various forecast offices where it is appropriate.

We will be expanding the use of that data starting early next year through an agreement which is called shared processing, which will interconnect the chief Navy operation for forecasting, which fleet numeric in Monterey, the chief Air Force activity, which Offutt Air Force Base and Suitland, MD. We will go into a specialized processing system where each of us works on a civic set of products, and then shares those products with the other services.

So there is a very close relationship there. We are using that data today, and we will be using more of it in the future.

Senator GORTON. I will make the announcement here that I have a series of questions from Senator Inouye which will be submitted to you in writing, which we would appreciate being responded to.

Dr. MCELROY. Yes, sir.

Senator HEFLIN. I don't know whether these are the same ones. My staff says that he had asked that we do it here.

Senator GORTON. Yes; they are the same ones.

Senator HEFLIN. Before I ask Senator Inouye's questions, I had a question in my mind since you had mentioned that the imagery of the continental United States would be used by the military. Pearl Harbor, and the military installations on the Islands of Hawaii come to mind.

Will there be a neglect of the military installations in Hawaii as a result of the movement of the one satellite, and what other facilities are available? What is your response to that?

Dr. HALLGREN. They obviously are not going to have the coverage. With the location at 98°, they will not have coverage from the geostationary satellite.

Senator HEFLIN. I did not understand you.

Dr. HALLGREN. They will not have coverage from the geostationary satellite in Hawaii whenever it is over at 98°. That was one of the choices that had to be made. We gave the emphasis to the hurricanes and covering the continental United States.

As we have indicated, we will be making maximum use of the polar orbiting meteorological satellite data both from the civil meteorological satellites, as well as the military satellites for acquiring as much information as we can for the Hawaiian area. We will also be making use of the Japanese geostationary satellite once it is put into orbit, I believe this fall; is that correct?

Dr. MCELROY. Yes.

Dr. HALLGREN. That is the situation.

Senator HEFLIN. In the first question of Senator Inouye, who is a member of the committee, he says:

> I am concerned about the potential hazards that the people in Hawaii and Alaska will be subjected to when the movement occurs due to this coverage gap.
>
> What plans does NOAA have to fill this significant, specific coverage gap until a new GOES satellite can be launched?

I suppose you have generally covered that. Do you want to add to that?

Dr. HALLGREN. I will say three specific things. One, we will be using the polar meteorological satellite imagery. Second, we are not going to hesitate to use aircraft reconnaissance in that area if there is a tropical storm or hurricane around the area. Third, we

presently have a buoy in operation to the south of Hawaii, and we are right now putting in a second buoy and it is under consideration in the supplemental request that is now before the Congress for two additional buoys for a total of four buoys around Hawaii.

Senator HEFLIN. He has another question:

Under current NOAA plans, the remaining GOES satellite would be moved further west during this winter hurricane season in the Pacific in order to provide coverage for Hawaii and Alaska. This coverage, however, would extend just ten degrees west of Hawaii, leaving the source of many tropical hurricanes in the South Pacific unmonitored.

Does NOAA feel that this ten degree margin is adequate to keep Hawaii sufficiently alerted to approaching dangerous weather fronts? If not, does NOAA plan to take action to receive consistent and complete weather data from the Pacific during the hurricane season?

Dr. HALLGREN. I believe that this is what I just covered in my last comment.

Senator HEFLIN. The third question is:

I understand that there is a possibility of reactivating the GOES–1 satellite to provide more complete coverage of the Pacific. This, I am told, would require the installation of new ground equipment to receive the GOES–1 transmission.

Is this a viable option that NOAA is considering? If so, is the necessary equipment readily available and can it be purchased out of NOAA's existing funds?

Dr. McElroy. Yes, sir, that is one of the options that we are looking at in addition to looking at expediting the schedule on GOES–G&H.

We have, purely by accident, an antenna on order which will meet this need. It was being purchased for another need; however, it can be installed at our Wallops facility, and will largely meet the need. It may be that there is a small amount of money which is required to make it totally suitable for this purpose.

We are working on getting an answer right now, and we are also looking to see what funds we could make available from within our own resources. We will be advising you on that next week, perhaps.

Senator GORTON. Thank you both very, very much for your helpful and enlightening testimony.

We are adjourned.

[Whereupon, at 12:17 p.m., the subcommittee adjourned.]

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR RIEGLE AND THE ANSWERS THERETO

Question. Most of the large storms that hit the American Midwest during winter form in the central Pacific ocean or in the Gulf of Alaska. Yet even moving GOES-6 westward at the end of the eastern hurricane season will not provide as much coverage of these Pacific regions as two satellites provided. How will this reduction in satellite coverage affect weather forecasts and winter storm warnings for the Midwest?

Answer. Changes in the upper air patterns in the central Pacific and Gulf of Alaska do affect the weather in the American Midwest and the loss of one GOES satellite will make it more difficult to observe this offshore area. The westward movement of the remaining satellite will only partially alleviate this problem. However there are other supplementary systems including polar orbiter satellites such as NOAA-6 and NOAA-7 which provide both imagery and quantitative upper-air measurements of temperature and moisture in the North Pacific. Polar orbiting satellites observe this area approximately every two hours and composite images created from successive orbital passes will be generated and distributed to NWS forecasters up to five times per day. These composite images while not as timely as the 30 minutes imagery provided by geostationary satellites will identify major weather

features in the area. In addition, data from NOAA's ocean buoys and upperair temperature and moisture profiles measured by NOAA-6 and NOAA-7 are routinely processed in computer-based mathematical models of the atmosphere. The models project existing weather features up to 5 days into the future. These projections are presented to NWS forecasters as the basic guidance for use in making daily forecasts throughout the United States. Since the weather features in the Gulf of Alaska take several days to translate to the Midwest and sufficient coverage exists throughout the coterminous U.S. and near Pacific area from the existing GOES-6 satellite, no significant loss of forecasting skill is expected in the Midwest. However, 3 to 5 day forecasts for the U.S. northwest and Alaska will be more difficult.

Question. What contingency plans does NOAA have if the remaining geostationary satellite, GOES-6, fails before GOES-7 can be launched? What, if anything, can be done to compensate for such a failure? And how would this kind of failure affect weather forecasts and storm warnings for regions such as the Midwest?

Answer. NOAA prepared a FY 1984 Supplemental Budget initiative to manipulate the data acquired by our polar orbiting satellites in such a way as to provide more useful imagery coverage in the data-void North Pacific, Anchorage, Honolulu, and San Francisco areas. Digital polar orbiter imagery acquired every 100 minutes over Alaska and every 4 to 6 hours at lower latitudes can be processed and fitted with earth location grids and joined together to form image composites. The composite images can be distributed on the present GOES distribution system to all NWS Forecast Offices. Similar efforts to create image composites are already being done on NOAA's large scale computers in Suitland, Maryland. Composite imagery is 4 to 6 hours old before distribution and such efforts, while useful in identifying the existence of large scale features such as major winter storms and hurricanes, offer little support relative to tracking their movement and short term intensification. Also, since a sequence of pictures 15 to 30 minutes apart is required to identify and track short-term phenomena such as thunderstorms or indicators of flash flooding, polar satellite imagery is not useful for severe weather watch and warning efforts in the Midwest.

Question. Our neighbors in Canada also depend on weather information from the GOES SATELLITES. How will the failure of GOES-5 and the movement of GOES-6 affect forecasts of Canadian weather?

Answer. The wintertime oceanic storms which move across the North Pacific and Gulf of Alaska affect Canada as well as the U.S. Moving GOES-6 600 miles westward to an equatorial location south of New Mexico will enable forecasters in both countries to see more of this storm-prone region. However this effort will only partially alleviate the problem. A movement further west would result in the loss of effective GOES imagery in the Northeast U.S. and Canadian Maritime Provinces. Canadian forecasters have access to both the imagery and quantitative data derived from polar orbiting satellites. Canada, because of its northern location, makes extensive use of polar data but the loss of a GOES satellite dedicated to Pacific storm surveillance will cause some difficulty for forecasters in western Canada. Because of the field of view of GOES satellites, the Maritime Provinces will be on the edge of useful imagery.

Questions of Senator Heflin and the Answers Thereto

Question. In general, how do geostationary and polar satellites contribute to NOAA's ability to detect severe storms such as hurricanes and its ability to provide accurate, timely warning to our citizens? What kinds of information are available to storm forecasters when two geostationary and two polar satellites are operating over the United States?

Answer. A satellite observing system which includes two geostationary and two polar satellites provides coverage of dynamic weather events over not only the contiguous 48 states, but also a major portion of the Central and Eastern Pacific Ocean and most of the Atlantic Ocean. Both Hawaii and Alaska and the surrounding oceanic areas are viewed by a two geostationary satellite and a two polar orbiter satellite system. This full complement of satellites allows nearly continuous coverage of all major weather features such as tropical storms and hurricanes over areas which extend several thousand miles from the coverage of all major weather features such as tropical storms and hurricanes over areas which extend several thousand miles from the coasts of the United States. Under such a configuration hurricanes which potentially threaten any part of the U.S. are spotted up to 10 days before landfall.

Over the conterminous U.S., geostationary imagery from GOES satellites is available every 30 minutes for use in the indentification of severe thunderstorms, torna-

does and flash floods. Early identification of the atmospheric features which cause these phenomena are a vital part of the NWS's severe weather watch program. As the severe weather develops, continuous monitoring provided by the imagery supports the issuance of timely severe warnings by local forecast offices.

Both polar and geostationary satellites are equipped with the instruments which measure the temperature and moisture through a series of vertical levels in the atmosphere. These profiles derived at regular vertical and horizontal intervals over oceanic areas provide a quantitative 3-dimensional measure of temperature and moisture in areas where few observations are available. The observations are collected and processed in computer-based mathematical models of the atmosphere which project these and other weather observations forward in time. The final product of this processing is a series of forecasts which project the development and movement of major meteorological systems. These forecasts, presented in 12 hour increments from observation time to three days, constitute the basic guidance forecasts issued to NWS forecasters. Forecasters in local offices use this guidance to prepare detailed forecasts of daily weather. The quantitative information derived from satellite data gathered over data-void oceanic areas is an important first step in this process.

Question. What do we lose—in terms of information, accuracy of forecasts, and timing of storm warning—by having only one instead of two geostationary satellites over the United States? For instance, will we be able to detect hurricanes as quickly, especially ones that form off the coast of Africa? Will our citizens receive as much advance warning? Will hurricane forecasts be less accurate?

Answer. The NWS has tried to reduce the effect of the loss of GOES-EAST by moving the remaining satellite, GOES–6, to a location over the central United States. From this position the satellite will routinely provide imagery extending from just east of the Hawaiian Islands to the mid-Atlantic extending from just east of the Hawaiian Islands to the mid-Atlantic by the European geostationary satellite METEOSAT and over the mid-Pacific by the Japanese satellite GMS. Some loss of information regarding the detection, monitoring and forecasting of hurricanes will occur in the East Atlantic where tropical storms develop. However, in West Atlantic, Caribbean Sea, and Gulf of Mexico where mature hurricanes threaten the coastal United States and Carribean countries, the central location of GOES–6 will routinely provide imagery every 30 minutes. A minimum of three to four days of hurricane surveillance will be provided to the East and Gulf Coasts. However, only one to two days surveillance will be given to the Caribbean Islands including Puerto Rico.

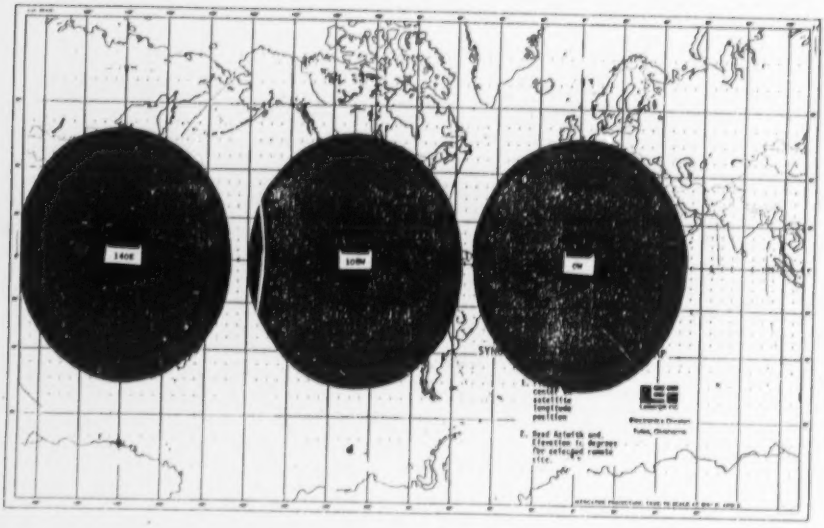
In the Eastern Pacific area, GOES coverage of tropical storms and hurricanes which develop off Central America and Mexico will be unchanged and will continue to provide reasonable tracking of storms which often affect the Southwestern U.S. with heavy rainfall. However in the Central Pacific, GOES coverage extends only up to the vicinity of Hawaii where the imagery becomes degraded. Hurricanes can and do affect the Hawaii Islands and supplementary systems including data buoys are being implemented near Hawaii as part of the NWS's acquisition plan. This action will partially compensate for the loss of optimum GOES imagery near Hawaii. Currently, two buoys, (250 miles northeast and northwest of Hawaii) are in place and two more are planned for deployment southwest and southeast of Hawaii. In addition we are examining ways to augment polar satellite data acquisition and processing in Honolulu and San Francisco.

Question. When will NOAA move the west coast satellite (GOES–6) eastward, and when do you plan to move it westward again?

Answer: GOES–6 was started eastward on August 1 and will be at its summer position of 98° W on or about August 30, 1984. On or about October 18, 1984, GOES–6 will be moved to its winter position of 108° W.

Question. Will the Southeast receive coverage during the entire length of the upcoming hurricane season?

Answer. The attached charts show the coverage from GOES–6 at both 98° W and 108° W. In both instances the southeast U.S. is covered.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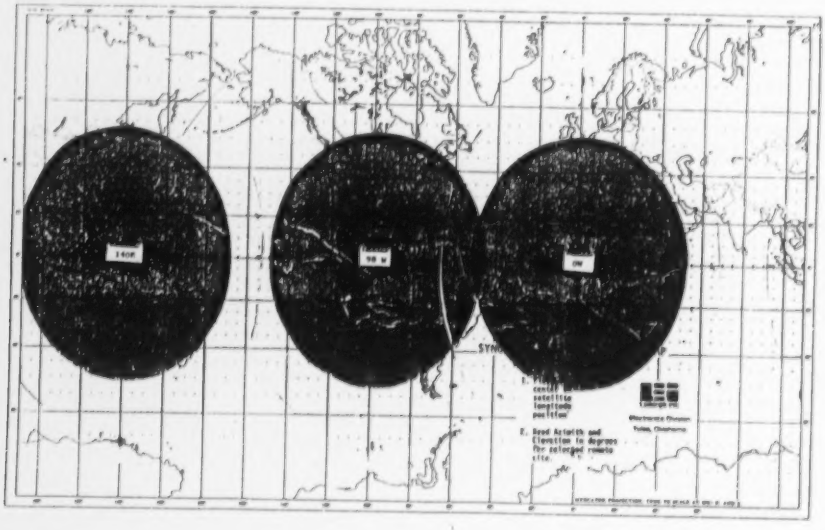
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Question. Will the satellite be moved eastward again next summer to cover the next hurricane season?

Answer. On or about May 9, 1985, we intend to move GOES–6 back to 98° W.

Question. What might be the economic impact of less advance warning of hurricanes.

Answer. Less advance warning and the subsequent loss of accuracy and forecast credibility will increase the risk of the loss of life and property. Each year as the coastal population increases, hundreds of millions of dollars in personal and corporate property is placed in areas which are vulnerable to ocean surges and high winds associated with hurricanes. Less advance warning of hurricane landfall reduces our ability to secure or remove threatened property.

Population evacuation studies conducted over eight areas in the southern and eastern United States indicate that it takes 20–30 hours at a rate of tens of thousands of people per hour to evacuate threatened coastal areas. A loss of timeliness and forecast accuracy could result in many thousands of people not evacuating such areas as the barrier islands on both the Atlantic and Gulf Coasts. Significant loss of life would be the result.

Question. How well will the one satellite cover storms this winter along the East Coast and throughout the Southeast? Will forecasting and warnings be improved?

Answer. During November when the hurricane monitoring task is completed, the GOES–6 will be moved 600 miles westward to an equatorial location south of New Mexico. with only one GOES satellite available, this position is considered optimum for wintertime surveillance of storms of both the East and West Coasts. Since the Gulf and East Coasts and several hundred miles of adjacent oceanic areas will also be within the maximum viewing range, no significant change in forecast or warning capability is expected. The westward satellite movement will partially offset the loss of one GOES satellite by enabling forecasters on the West Coast and in Hawaii to see more of the oceanic areas of the data-void North Pacific where sever winter storms develop and move toward the coast.

Question. Do you know whether the construction and launching of the next geostationary satellite can be accelerated? If not, when might you be able to tell this Committee about the feasibility and cost of accelerating that satellite.

Answer. We have been exploring the question of possible acceleration of the GOES G schedule with NASA and Hughes Aircraft Company, supplier of the GOES satellites. We have found that some acceleration is possible, if overtime and additional staffing are added for night and weekend work. A further acceleration is possible if the test program is shortened by eliminating subsystem level testing where "all-up" satellite level measurements can verify proper operation. Suggestions for acceleration made by Hughes will be refined (by Hughes) during the next month and then evaluated by NASA and NOAA technical staff. We must be assured that the test deletions will not increase the risk of premature failure of the satellite.

There is a significant risk associated with the suggested accelerated GOES G proposal. If problems are found during satellite level testing, their impact on overall schedule is much more severe than if they had been found in lower level testing. This results from the added requirement to first remove systems from the satellite before troubleshooting and repair can even begin.

Our initial assessment of the suggestions for schedule enhancement has been favorable. Though it is uncertain whether all of the test deletions will be acceptable, it is likely that some will be. Though the new plan incorporates a high risk of schedule erosion if problems occur, it is anticipated that these actions will help us to deliver GOES G up to six months earlier than previously required of Hughes. Technical risk, though increased by this plan, may not be unreasonable.

Cost of this schedule enhancement is twofold. First, the added overtime and weekend work will cost on the order of $1–2M. In addition, it is likely that GOES H will fall behind schedule as contractor resources are brought to bear on the GOES G qualification. This will add another $1–2M to the cost of GOES H and about $1M per month in launch services costs for each month the launch is delayed beyond our current projection. This later cost will result in a requirement for additional funding only if the slip results in a launch later than August 1986, which is the current contractual date for the satellite.

NOAA and NASA with Hughes will look at the revised test plan in detail during the next month. If we become convinced that the technical risk is small, we will authorize Hughes to continue to test the system according to the revised. If the technical risk is excessive, we will revert to the original test plan to best assure that the satellite, though delivered later than we desire, will meet its operational goals through the launch of GOES I now planned for 1990.

During the month as the accelerated schedule plan is definitized, Hughes will be looking at the probable cost implications of this plan in detail. By mid-September NOAA should have the Huges cost estimate and analysis and be in a position to determine whether it is feasible to accelerate the procurement schedule without greatly increasing the risk of a premature satellite failure.

Question. During the hurricane season, can additional aircraft flights and greater use of ocean buoys help compensate for the loss of satellite information? If so, what steps are you taking now to ensure that additional information will be available from aircraft and buoys?

Answer. Aircraft reconnaissance had long been a major source of accurate information concerning the exact location, central pressure, and wind speed of a hurricane. The NWS and U.S. Air Force have already implemented a plan to fly reconnaissance flights into Atlantic hurricanes from Antiqua in the Lesser Antilles (near the eastern edge of useful GOES coverage) and into Pacific hurricanes from McClellan AFB in California. Two aircraft are assigned to each base and daily missions will be flown into any storm approaching either the Caribbean or Hawaii. If a storm moves to the immediate vicinity of Hawaii, the base for Pacific operations will be moved to Hickman AFB in Honolulu.

As mentioned, data buoys have already been placed 250 miles northwest and northeast of Hawaii and two more are to be deployed southeast and southwest of Hawaii.

Question. I understand that Japan may soon launch a weather satellite of its own. If that launch is successful, will the United States be able to obtain pictures and other information from it?

Answer. The Japanese did successfully launch a new weather satellite in early August. We have the capability of receiving low-resolution data from that satellite when it is placed in operational service. In addition, we will be requesting funds to upgrade that receiving capability so that we can copy the higher resolution data from that satellite.

Question. How would that information affect our coverage of Pacific weather?

Answer. The movement of GOES–6 from its Pacific position will cause a loss of continuous satellite imagery north and west of Hawaii and over the Gulf of Alaska. There will be significant difficulty adjusting to the loss of imagery every 30 minutes. The GMS–3 satellite data, when placed into operation, will only provide a view of the meteorogically important Northern Pacific Ocean south and west of the Aleutians every three to five hours.

Question. And if we get access to the Japanese data, could or would the existing American geostationary satellite be left more over the eastern United States?

Answer. As you can see in the attached diagrams, the coverage from the Japanese satellite, while useful, still does not give adequate coverage of winter storms which threaten the West Coast. The winter weather that affects the U.S. East and Gulf Coast is reasonably well covered with the satellite in its winter position of 108° W.

Question. Why do we have no backup satellites available at this time? Is this a matter of budget limitations?

Answer. The GOES 4, 5 and 6 spacecraft were specified to have an operational life of 5 years. When these spacecraft were procured, it was calculated that GOES 4 and 5 would be in service until a follow-on spacecraft was ready for launch in the FY 1985/86 period. GOES 6 was included with the GOES 4 and 5 as the "backup" satellite in case we experienced a launch failure or a premature in-orbit failure.

The actual lifetimes of these spacecraft have not met their design goals; GOES 4 failed after 26 months and GOES 5 failed after 38 months in orbit. GOES 6 was launched in FY 1983 as the replacement for GOES 4, leaving no replacement for the second failed spacecraft.

We chose to take a calculated risk, but the absence of a backup satellite is not attributable solely to budget limitations. Decisions on how many spacecraft to include in each spacecraft procurement are influenced by several factors. The prime consideration is the need to provide continuity of service. Other factors include budgetary limitations, anticipated changes in technology, and procurement strategies to ensure the most economical cost over the life of the system. In the case of GOES 4, 5, and 6, our decision to procure three spacecraft appeared to satisfy all these factors:

Three spacecraft designed for 5 years lifetime should have met our spacecraft mission needs with adequate backup.

A three-spacecraft procurement had the least impact on current budgets.

The uncertainties associated with the projected launching environment when GOES 4, 5, and 6 were procured made the procurement of more than three spacecraft impractical.

The three-spacecraft procurement enabled the Government to have a competitive procurement.

Question. Can you tell us why so many of our American weather satellites have failed earlier than planned? Do the failures stem from design flaws, problems with contractors, or some other problem? In your judgment, what can we do to prevent today's kind of problem from occurring in the future?

Answer. Although plagued by a recent series of premature failures, the NOAA meteorological satellites have generally met, and frequently exceeded, their design life. Satellites of the NOAA polar program have been particularly successful. The large number of electromechanical components required (instruments, tape recorders, momentum wheels, etc.) result in a spacecraft designed to operate in orbit for two years. With the exception of NOAA-8, which became unusable when the primary clock failed after one year, satellites of the TIROS-N/Advanced TIROS-N series have exhibited average longevities of over three years. The program has maintained data continuity throughout that period by judicious utilization of available space resources, though suffering a launch (NOAA B) and premature (NOAA 8) failure. This is a record of which NOAA and NASA, who manage our satellite procurements, are proud.

The geostationary satellite program success rate has not equalled that of the polar. Though we believed that the relative sparcity of electromechanical devices on the GOES would allow us to design a satellite with a longevity approaching five to seven years, our optimism has not been validated by experience. GOES satellites have achieved lifetimes not dissimilar to those from the polar program. Here the failure mechanism, too frequently, turned out to be a tungsten filament bulb which did not achieve its expected longevity. Unfortunately, the problem which was first identified in GOES 2 and 3 after two years in orbit, was not recognized in time for us to modify the GOES 5. We were able to incorporate additional bulbs into the GOES 6 mechanism, and are again optimistic that we will achieve our design life for this satellite. Further improvements are planned for the satellites still on order today.

Problems of the type encountered by the GOES satellites are difficult if not impossible to anticipate. The bulbs used in the GOES 5 contained a tungsten material different from that of bulbs in previous satellites from which significantly longer lifetimes were obtained. The difference in material properties was not evident during ground qualification of the bulbs for flight, and only showed up in extended life tests. By the time the problem was identified and its cause determined definitively, we had already committed two additional satellites to launch. The GOES 5 failure after three years in orbit is directly attributable to this problem. The GOES 4 failure which preceded, was caused by a short circuit, which developed in a different component of a radically new design which was used to provide new data useful in predicting severe storm conditions, while (at the same time) remaining whithin the constraints imposed by available launch vehicles.

In general then, it can be said that the problems encountered by the GOES program are technological in nature. These problems have been compounded by a program plan that resulted in satellite procurements being limited to two or three spacecraft buys by budgetary constraints. The reliability model utilized in assessing the risk associated with this approach has, in retrospect, been shown to be unrealistically optimistic. To avoid problems of this type in the future, we have retructured our program in two ways. These are:

(1) We have asked NASA to stress reliability and longevity in developing the GOES-Next satellites for our use. We believe that a five-year longevity should be attainable, now that the weight and volume constraints imposed by available launch vehicles have been removed by transition to the space shuttle.

(2) We have issued an RFP for the GOES-Next series of satellites which allows us the option to purchase five satellites. This multi-satellite buy would provide economies of scale. More importantly, it would assure that replacement satellites are always available to maintain service continuity to our users should we encounter a launch or premature satellite failure.

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